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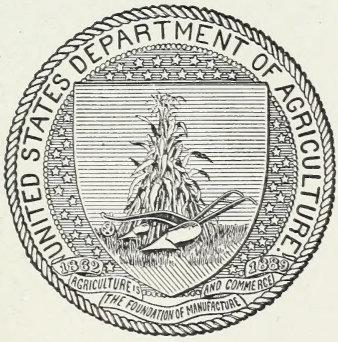
U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 190.
B. T. GALLOWAY, *Chief of Bureau.*

ORCHARD GREEN-MANURE CROPS IN CALIFORNIA.

BY

ROLAND McKEE,
SCIENTIFIC ASSISTANT, OFFICE OF FORAGE-CROP INVESTIGATIONS.

ISSUED OCTOBER 27, 1910.



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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 2, 1910.

Sir: I have the honor to transmit and to recommend for publication the accompanying manuscript, entitled "Orchard Green-Manure Crops in California," by Mr. Roland McKee, Scientific Assistant in the Office of Forage-Crop Investigations, and recommend its publication as Bulletin No. 190 of the Bureau series.

Leguminous cover crops are now extensively used in California citrus orchards, but only to a slight extent in deciduous orchards. Owing to peculiar conditions certain legumes are especially adapted for use in that State, while their usefulness elsewhere is limited.

The results presented in this bulletin are based on the investigations that have been conducted at Chico, Cal., and in cooperation with many orchardists for the past five years.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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ORCHARD GREEN-MANURE CROPS IN CALIFORNIA.

INTRODUCTION.

The use of green-manure crops for the maintenance of soil fertility is one of the oldest of agricultural practices. In California such crops have been used in a limited way for a long time, yet it is only within recent years that their practical value has become fully recognized. The growing of these crops has attained its greatest development in the citrus orchards of the southern part of the State, where they have been longest used.

As far back as the early nineties some of the more progressive orchardists were beginning to realize the necessity of some such practice as green manuring and to this end utilized the natural growth of bur clover and other weeds, such as alfilaria,[a] brome-grasses, etc. The Canada field pea was the first of the legumes to be used extensively as a green-manure crop, and by 1900 it was being quite generally grown in the citrus orchards of the southern part of the State. Common vetch and bur clover were also being utilized at this time.

In many parts of California, green-manure crops have not been used to any extent, but not entirely without reason. That their use can be made much more general than at present is quite certain, and as their value is more fully appreciated and their adaptation to the various sections demonstrated their use will be proportionately increased.

For a number of years the Bureau of Plant Industry has been working to secure better crops for green manuring than the ones now used and to aid in the demonstration of the adaptability of the ones now being grown. The Agricultural Experiment Station of the University of California has also done extensive work in demonstrating the value of various green-manure crops in that State.

In California the work of the Bureau of Plant Industry has been carried on in cooperation with orchardists and farmers throughout the various sections and at the United States Plant Introduction Garden at Chico, where extensive tests have been made. This work has clearly indicated the superiority of certain crops over others and their adaptation for varying purposes and conditions.

[a] Known also as alfilerilla and pin-grass.

THE ORCHARD DISTRICTS OF CALIFORNIA.

The orchard districts of California so far as green-manure crops are concerned at once divide themselves into the citrus and the deciduous fruit districts. These are again readily divided into the northern and southern citrus districts and the irrigated and nonirrigated deciduous sections.

The two citrus districts have a definite geographical distinction, while with the deciduous orchards water is the differentiating factor, without reference to any geographical distinction. The citrus districts are quite definite in area. The southern district is confined to what is known as southern California proper and includes the territory south of the Sierra Madre Mountains and north along the coast to Santa Barbara. The northern district includes a narrow strip on the east side of the San Joaquin Valley from some distance south of Porterville to Lemoncove, Tulare County, on the north; a similar but smaller area in Fresno County; a small area in the Sacramento Valley, centering about Oroville and Palermo; and various small areas in other parts of the valleys and foothills.

Conditions with regard to water, soil, climatic or seasonal variations, etc., are quite different in these various sections, and the plant best suited to a certain area must be carefully considered in determining the probability of success with a green-manure crop. Practices satisfactory in one locality may be unsuited to another, and the crop best adapted to one section may not be adapted to another.

SOUTHERN CITRUS SECTION.

The seasonal conditions of the southern citrus section are such as to make this the most favorable part of the State for growing green-manure crops. The locality and climatic conditions are such that these crops are practically never injured by frosts, and the mild winters favor vegetative growth at that time of the year.

In contrast with the deciduous sections, where there is usually a heavy rainfall, here the rainfall is usually light. However, as irrigation is given throughout the dry season the conditions are favorable to the sowing of a green-manure crop early in the fall, thus giving sufficient time for considerable growth before the cold weather of winter.

The soils vary considerably in composition and mechanical texture, but as a general rule are of such a nature as to permit working at almost any time during the winter, except after heavy rains, thus favoring the turning under of a green-manure crop. While some soils in this section are a rich loam and contain considerable organic matter, as a rule they are quite deficient in this respect. That green manures need to be more extensively used is evident.

NORTHERN CITRUS SECTION.

The northern citrus section, as previously stated, comprises a small region in the San Joaquin Valley, centering about Porterville and Exeter, and a smaller section in the Sacramento Valley, centering about Oroville and Palermo, besides small areas in various parts of the valleys and foothills of the State. The conditions in this district differ very much from the conditions in the southern California district, and in these differences is found the reason why green-manure crops have been but little used.

The seasonal conditions at the north while favorable to the growth of green-manure crops are less favorable for their handling. The rainy season is quite definite, extending through January and February, and sometimes into March. The soil, which is heavy, dries out slowly during the winter season, often making it impossible to get into the orchard to turn under a crop at the proper time. Thus, when the season for turning under is delayed, a heavy vegetative growth is objectionable in that it makes the land hard to work and at the same time by shading prevents it from drying out to allow of cultivation as early as otherwise would be the case. The soils throughout the northern district are with few exceptions of the very heavy nature referred to, and for this reason a heavy vegetative growth is often a hindrance to proper handling. While the immediate effects of a green-manure crop may be undesirable, there is but little question that these lands need to be made lighter by the addition of humus, and results that appear at the time as unfavorable can well be tolerated when the ultimate effect will be an improved condition.

Green manures have been used but little in the northern citrus section. However, the results from a few plantings, together with the experimental work done, clearly show that by early seeding a good green-manure crop can be grown and in most cases can be profitably used.

DECIDUOUS ORCHARD SECTIONS.

While the deciduous orchards are scattered throughout the State of California they are largely in the northern part and are mostly located on the fertile lands of the various river valleys and the low foothills. Green-manure crops have not been used to any extent in these orchards, and practically the only thing approaching such a crop is the volunteer growth of bur clover, which is usually sufficient by the time the orchards are plowed in the spring to yield considerable humus.

The problem of growing a green-manure crop in deciduous orchards is quite different from that of growing the same crop in citrus orchards. This difference lies principally in the fact that the former

are not irrigated, or if water is applied it is early in the summer, and not in the fall when it could be utilized in starting the crop.

Winter rains must be depended upon to germinate seed sown in the fall, and only in the most favorable seasons are they early enough to allow much growth before cold weather. When the first rains come late, but little growth is made by fall-sown seed until the warmer weather of the latter part of winter or early spring. Thus, only in the most favorable years will the growth be sufficiently early to allow its utilization for green manure. Where water is available for fall irrigation the question ceases to be one of the possibility of growing a good green-manure crop and becomes one of the returns justifying the expense.

CONDITIONS UNDER WHICH GREEN-MANURE CROPS SHOULD NOT BE USED.

There are some sections in which green-manure crops can be grown satisfactorily, but their utility nevertheless seems questionable. This is especially true in lemon orchards having a very heavy soil, and to a less degree in orange orchards. By a heavy soil is not meant a heavy loam, but an adobe or a soil approaching that texture. On such soils the discontinuance of cultivation which is necessitated by the growing of a green-manure crop allows the soil to become quite hard and packed, thus permitting very imperfect aeration. This is a most undesirable soil condition to maintain during a period of several months, and its injurious effects may be seen in the unthrifty appearance of the trees. Where this effect is very marked it is undoubtedly best not to use a green manure, but to use stable manure instead, if such is available.

In the Porterville and Oroville citrus districts, where the soils are quite generally of a heavy type, the foregoing statement does not apply as definitely as in the southern California districts. This is due to seasonal differences. The trees in the two former sections have a more nearly dormant period of growth during the early winter than those in the latter, in which case the effect of noncultivation is not so marked. Where on account of heavy soils it is not advisable to grow a green-manure crop, stable manure, if available, should be used in lightening the soil.

QUALITIES DESIRABLE IN A GREEN-MANURE CROP.

No one plant possesses all the desirable qualities of an ideal green-manure crop. However, in the various crops used for such purposes, practically all the desirable qualities are represented, though varying in degree. The conditions under which a green manure is to be grown determine to some extent whether a certain quality is

desirable or objectionable and must be taken into consideration in selecting the best crop to grow.

A green-manure crop should be a legume wherever possible, in order to obtain the addition of nitrogen to the soil. It is also necessary that a good growth be made, in order to have a large quantity of organic matter to turn under and incorporate with the soil. Along with good growth should be a heavy development of nodules on the roots, as this is believed to indicate great ability to fix atmospheric nitrogen.

The quality of being able to stand trampling with a minimum of injury is very important where the crop will be subject to such injury, as is the case in citrus orchards where the picking of fruit takes place while the green-manure crop is yet growing. Uprightness and nontwining stems are also desirable where an ordinary moldboard plow is depended upon for turning under the crop. However, if a disk plow is used or the crop is worked in with an ordinary disk harrow, this does not make so much difference, and where the growth is not allowed to become too rank little difficulty is experienced in plowing it under.

The texture of the stem should be such as to decompose readily. Practically all crops, however, if turned under at the right stage of growth decay readily. Thus, the question of decomposition is one of turning under the crop at the right time rather than one of selecting a crop that will decay readily.

That the cost of a green manure may not be too great, it is necessary that the price of seed be reasonable as compared with the results to be obtained.

METHODS OF HANDLING GREEN-MANURE CROPS.

The methods of handling green-manure crops in California are quite similar throughout the various sections. However, some variation in practice exists among orchardists in the same neighborhood, as well as among those of different localities.

The following methods are practiced in the citrus and walnut orchards of the southern part of the State, where green manures have been most generally grown.

PREPARATION OF THE LAND.

Since clean culture is practiced throughout the year in citrus and walnut orchards except when a green-manure crop is being grown, the land can be prepared at any time for the seeding of such a crop.

The general practice is to prepare the land for seeding by plowing or disking and harrowing immediately after an irrigation. This puts the land in good condition for the seeding.

SEEDING.

The most successful growers of green-manure crops sow vetch and bur clover in the first half of September, and peas during the latter half of the same month. Early seeding is being much more generally practiced now than it was a few years ago, when the greater part of the crop was sown in October. The time of irrigation of an orchard determines to some extent when a green-manure crop shall be sown, as water is not always available at the time desired. However, when water is available the time mentioned is that most generally favored for irrigation.

The seed is sown either drilled or broadcast and harrowed in.

IRRIGATION.

After the seed is sown and before it germinates, the land is prepared for fall or winter irrigation if necessary. The furrow method is the one most commonly used. This consists in making a number of shallow furrows between the rows in the direction the water is to flow, the method varying in different sections and with the lay of the land.

The basin method is used to quite an extent in the walnut orchards of the southern part of the State and in the orchards of the Santa Clara Valley.[a]

Nothing further is done, with the exception of irrigating if necessary, until the crop is ready to turn under. When a crop is sown in September it can be plowed under during February.

TURNING UNDER A GREEN-MANURE CROP.

In turning under a green-manure crop the common moldboard plow (see fig. 1), the disk plow, or the disk harrow is used. In using the first a sharp colter is attached, and where the vine growth is heavy a chain is also used. Sometimes the land is run over once with a disk harrow before plowing. This enables a heavy growth to be more completely turned under. During the past few years the disk plow has been very generally used, and for turning under a heavy vine growth it works more satisfactorily than the moldboard plow.

After plowing under a green-manure crop the land is harrowed, and as the crop decays cultivation is given. This at first is shallow, so as not to bring the vines to the surface, but later a deeper cultivation is given.

In sections having a very open soil or a sandy loam the disk harrow has been used very successfully in turning under a green-manure crop. The use of this harrow has been taken up with the idea that fewer surface-feeding roots of the trees are disturbed by its use than

[a] See Bulletin 145, Office of Experiment Stations, pp. 46–50.

is the case with the plow, for which reason it is thought by many to be more desirable. In working a green-manure crop into the soil with a disk harrow, four diskings are usually required, each disking, where the planting of the orchard will permit, being made at an angle with the previous one. On the heavier soils the disk harrow does not work so well and the plow is used almost entirely.

After turning under a green manure the land is kept well cultivated the remainder of the year.

For obtaining the best results a green-manure crop should be turned under early enough in the season to allow perfect decomposi-

FIG. 1.—View in a California orange grove, showing the method employed in plowing under a green-manure crop.

tion. In orchards this can be quite definitely designated, as the turning under should take place before the trees start growth in the spring. This means, for citrus orchards in southern California, not later than February. In northern California the season is of necessity a little later on account of the generally wet condition of the soil at that time. Where the factors relating to other crops and a season favorable to decomposition do not have to be taken into consideration, it perhaps is safe to say that to obtain the best results most legumes should be turned under about the time the first pods form, or a little earlier.

INOCULATION.

The question is often asked whether it is not advisable to inoculate seed to be sown on land that has not previously grown that crop. In California it has been found that the bacteria necessary to nodule formation on the more common leguminous crops are present in most soils. The first seeding may not, however, be as abundantly inoculated as desired, and in some sections the bacteria essential to certain crops seem to be entirely lacking in the soil.

In northern California it has been observed that horse beans are not inoculated the first year they are grown on soil that has not pre-

FIG. 2.—Experimental plats of horse beans at Chico, Cal., showing the striking superiority of the noduled plants.

viously grown this crop. (See fig. 2.) Thus, to obtain the best results, it is necessary to inoculate the crop the first year. The difference between an inoculated and an uninoculated crop of horse beans in the Sacramento Valley is very marked and is practically the difference between success and failure. In southern California this crop does not require artificial inoculation, the soil being inoculated.

In the inoculation of horse beans the surest results are obtained by securing soil from an inoculated plat or field and mixing this with the seed at the time of seeding. In this way but little soil will be required to inoculate a large area, and practically no extra time or

labor is necessary. The inoculation of this crop may also be attained by spreading inoculated soil over the field at the time of seeding and working it in with the seed, or the seed may be inoculated with pure cultures of the bacteria which form nodules on the roots of this plant. Such cultures have been distributed by this Department for several years, and the results obtained from their use have been favorable in many cases.

COMMERCIAL FERTILIZERS.

In the citrus orchards of California commercial fertilizers are quite generally applied, while in few deciduous orchards are fertilizers used in any form. Where fertilizers are used they are usually applied in connection with a green-manure crop.

The value of a green-manure crop is largely due to the part it plays in liberating plant food in the soil. In the decay of organic matter and the giving off of carbonic-acid gas, the action on phosphorus and potassium compounds is such as to make them more available as plant food. Vegetable acids, which are always more or less present with a green-manure crop, also aid in liberating plant food. Thus, elements present in a soil but not available as plant food may be made so by the use of a green manure.[a]

From the facts just stated it will be readily seen that a green-manure crop may serve a useful purpose when used in connection with commercial fertilizers, especially where the various plant-food elements are only partially available in the soil.

WINTER GREEN-MANURE CROPS NOW USED IN CALIFORNIA ORCHARDS.

The green-manure crops now used in California, in the order of their importance, are as follows: Common vetch, Canada field peas, bur clover, fenugreek, hairy vetch, and Indian melilot.

Common vetch and field peas are by far the most extensively planted, while hairy vetch and melilot are very little used. Bur clover and fenugreek are used to but a limited extent, although they are of considerable importance.

COMMON VETCH.

The common or spring vetch (*Vicia sativa*) is the most extensively grown green-manure crop in California. It is being grown throughout the orchard sections wherever green-manure crops are being used at all (see fig. 3). It is adapted to quite varied conditions and succeeds in all sections of the State. In the coast sections, as well as inland, it makes a good growth and does well on both the light and the heavy soils.

[a] See E. W. Hilgard, Soils, pp. 19–21, 63, 126, and 394–396.

The qualities of common vetch are such as to make it well adapted for green-manure purposes, especially in citrus orchards, and orchardists in general are growing it in preference to field peas, which were largely grown a few years since.

Common vetch makes a vinelike growth similar to that of peas, but the vines are less succulent and so are able to stand considerable hard usage without much injury. Thus, in orchards when picking fruit and doing other work, the trampling which is unavoidable interferes but little with the growth of the vetch. The root system, which is quite extensive, lies largely near the surface and ordinarily is well covered with nodules.

FIG. 3.—View in an orange orchard in southern California, showing common vetch grown as a green-manure crop.

When used for a green-manure in southern California common vetch is usually sown during September and the first half of October.

However, better results are being secured with the earlier seedings, and in most years to obtain the best results it is quite essential that the crop be sown during the first half of September. When thus sown the plants make a good growth before cold weather and continue to grow during the winter. But if the seed is sown late and the plants have made but a small growth before the cold weather, they then make little or practically no growth until the warmer weather comes in the latter part of the winter.

In February, 1908, at Redlands, Cal., which is representative of the citrus sections, plantings of vetch made in September, 1907, were from 12 to 15 inches high and in a fine condition to turn under. Plantings made in October, 1907, from a month to six weeks later, were but 6 inches high. During the past season similar results were noted.

The rate of seeding varies from 40 to 60 pounds per acre. Forty pounds per acre has been more generally recommended, but the heavier seeding is giving much better crops and more than makes up for the difference in the cost of the seed.

Early as well as heavy seeding is quite commonly recognized by growers as necessary for obtaining the best results, and a deeper seeding has also been found essential where the plantings are early. In northern California under irrigation, vetches should be sown about the first of October. They will then make sufficient growth to be turned under in February or March. This later season of planting in the northern part of the State is desirable in both citrus and deciduous orchards on account of the heavy winter rainfall, which does not permit turning under the crop as early as in the southern section. Later planting in the deciduous-orchard sections is also desirable on account of the possible injury from frosts when an early succulent growth is made, as would be the case with earlier plantings.

Experiments and observations have shown that vetch will make but little growth by February or March when sown in the fall without irrigation.

CANADA FIELD PEAS.

The field pea was among the first crops tried in California for green manuring and was the first one extensively used for this purpose. Its early use was partly due to the fact that seed was readily obtainable. At the present time it still holds a prominent place as a green-manure crop, and next to common vetch is most extensively used (see fig. 4).

Like the common vetch the field pea is adapted to varied conditions and has succeeded wherever green-manure crops have been grown. For making a growth during cool weather there is no other crop known that equals it; but it has other characteristics that make it less desirable for green manuring, especially in citrus orchards.

The root system of the field pea, which is very extensive, consists of a central or main taproot from which radiate the many finer laterals. The roots extend quite deep, and for this reason the crop is favored by many orchardists for breaking up "plow sole."

The vines, which are succulent and tender, are greatly damaged by the trampling necessitated during the harvesting of most citrus fruits; and on account of their making so much new growth during cold weather they are often severely injured by frost. Usually as the

plants approach maturity the lower portions of the stems become dry and wiry, making the turning under difficult.

Aphids, or plant lice, are very fond of peas and nearly every year their attacks occasion considerable damage. In the coast sections or those having more humid conditions, the crops also suffer severely from the attacks of mildew. Inland, however, there has been but little injury from this cause.

While field peas are in some ways objectionable they also have certain qualities that make them serve special purposes. Their ability to stand late fall planting and still produce a fair winter growth makes them especially valuable for such use when for any

FIG. 4.—View in an orange orchard in southern California, showing Canada field peas grown as a green-manure crop.

reason an earlier planting of other crops has not been accomplished, but if sown late only a very ordinary crop can be expected. While peas may be planted from the middle of September to the end of November, in southern California the best results are secured from September plantings. In the northern part of the State the middle of October is better for planting because the winter rains prevent the crop from being turned under until later in the winter. When planted early, peas in the north are also likely to suffer more severely from winter frosts.

Seventy pounds of seed per acre is the usual rate of seeding. This in some cases gives a very good crop but a thin stand, and therefore a light yield has been very noticeable in all orchard

sections. At least 80 pounds of seed per acre should be used, and unless seeding conditions are very favorable more rather than less is recommended.

During the past few winters the general crops of field peas and vetch throughout the orchard sections of California have shown that peas make a stronger individual plant growth than vetch, but do not make as heavy a yield of green manure. When sown during the latter part of September the peas have made a growth of from 24 to 36 inches, while common vetch made from 15 to 18 inches. This is representative of the usual comparative stem growth of the two crops. In the citrus orchards of southern California peas should be turned under early in February, and in the northern part of the State during the latter part of February or the first of March.

BUR CLOVER.

There are a number of kinds of bur clover, of which only two are yet much grown in California, namely, the common or toothed bur clover (*Medicago hispida denticulata*) and the spotted bur clover (*Medicago arabica*). The toothed bur clover is the one most commonly seen, being thoroughly naturalized, but the spotted bur clover, though less abundant, grows equally well. It differs from common bur clover in having a brown spot on each leaflet and longer and softer spines on the burs.

Bur clover makes a decumbent growth, the stems being rather small and quite succulent when young, but it withstands considerable trampling. The roots are shallow but numerous and usually have many nodules. The crop has been grown to quite an extent for green manure, but on account of its not making a good early-winter growth its use will always be limited. In orchards where bur clover has been once planted it will spring up for several years. This is due to the hard seeds that do not germinate the first year. In the citrus orchards of southern California bur clover is sown at the same time as vetch, which is during September and early October. To obtain the best results, seeding as early as possible in September is advised. Twenty pounds of seed (hulled) per acre should be used, care being taken to plant shallow, as deeply covered seed will not germinate but will hold over in the soil. The sowing of seed in the bur is not recommended, because the bur delays germination and occasions very uneven stands, to say nothing of the greater difficulty in sowing. However, there is no longer need of using seed in the bur, as clean seed can be secured in quantity from western seedsmen.

For use in deciduous orchards bur clover is of considerable importance and if properly handled will serve a very useful purpose. At the present time it is utilized only where it volunteers as a weed and can be turned under at the regular spring plowing of the orchard.

On account of the light growth usually made by a green-manure crop sown in the fall without irrigation, the expense of seeding a crop each year in this way is hardly justified. Through the use of bur clover this objection can be overcome by allowing the crop to reseed itself from year to year. In this way with a little care bur clover can be maintained in an orchard at small expense. If an occasional late season prevents the crop from ripening its seed before the orchard must be plowed, narrow strips can be left between the rows to mature, and in this way reseeding be accomplished. The fact that the seeds of bur clover do not all germinate the first year but hold over in the soil until the second or third year, or even longer, lends to the ease of maintaining the stand.

FIG. 5.—An individual plant of fenugreek, showing its characteristics.

Bur clover is at present most commonly introduced and maintained in orchards by the use of manure from old sheep corrals, which usually contains large quantities of the seed.

FENUGREEK.

Fenugreek (*Trigonella foenum-graecum*) is an upright-growing plant having a central stem which is more or less branched. A somewhat open top is formed when fenugreek is grown as an individual plant (see fig. 5). When grown in plats with little chance for individual development, but few branches are formed. The plants attain a height of 20 to 30 inches. The leaves, of which there is a medium number, are trifoliate, with cuneate or obovate thickish leaflets. The seeds, which are borne in long, pointed pods, are quite small (one or two lines long) and of a brownish-yellow color. The pods dehisce, or break open, tardily, making the crop one that can be handled easily for seed.

ADAPTATION.

Fenugreek is grown in quantity in California only in Ventura and Orange counties. The recognition of its value as a green-manure crop dates back to 1903, it having been distributed the previous year by the California experiment station. Since that time its use has gradually increased, and while it is only in Orange and Ventura counties that it has been used as a regular crop it has been tested and grown in a small way in all the citrus sections of the State (see fig. 6).

From tests and observations made during the past three years it seems quite evident that fenugreek is best adapted to the citrus sections of the State having the immediate coast influences. The climatic conditions of such localities are very favorable for fenugreek, and it is therefore in those sections that it has attained its best development. In sections farther from the coast, such as at Riverside and Redlands, and in the interior valleys of the State, quite good crops have been grown, but in such localities the crop is more exacting in its requirements as to time of planting, etc.

FIG. 6.—View in a walnut orchard in Orange County, California, showing fenugreek grown as a green-manure crop.

COMPARATIVE VALUE.

In comparative tests made at Redlands, Cal., fenugreek sown October 7, 1907, by the middle of February, 1908, had attained a height of 10 inches. Common vetch made but 6 inches of growth in the same time. At Pomona, Cal., fenugreek sown November 4, 1907, by the middle of February, 1908, had made a growth of 18 to 24 inches. Common vetch in comparison made but 8 inches of growth during the same time. At Chico, in northern California, fenugreek sown October 5, 1908, with irrigation, by the first of March, 1909, had made a growth of 12 to 15 inches, and of 16 to 20 inches by the middle of March. In other tests the fenugreek did

not make so good a showing, yet wherever sown early it has done quite well.

As to the quantity of green manure produced by fenugreek in comparison with other crops there are but limited data. At Santa Paula, Cal., weights of vetch and fenugreek were taken the middle of February, 1909, to determine the quantity of green manure produced. The plants growing in the space between four trees were cut and weighed green, and the yield per acre was computed from these weights. The fenugreek yielded 11,745 pounds per acre solid area, or 8,432 pounds orchard area, while the common vetch yielded 19,140 pounds per acre solid area, or 13,742 pounds orchard area. However, these figures do not justly represent the comparative yield of organic matter, as the moisture content of the vetch was undoubtedly much greater than that of the fenugreek, and the yield of dry matter of the two crops would have been much more nearly equal than is indicated by the figures given. At Chico, in northern California, fenugreek weighed green March 16, 1909, yielded at the rate of 13,721 pounds per acre. This was from plantings made October 5, 1908. In comparison, at Chico, common vetch produced but 2,831 pounds per acre.

Considering the convenience and cost of handling, fenugreek is superior to any other green-manure crop now being used. The upright habit of the plant makes the crop easy to turn under. The roots have many nodules and form a system similar to that of the field pea.

Fenugreek is especially desirable for an orchard green-manure crop, owing to the fact that no insect pests seem to be harbored by it. This point has been especially noticeable in sections where the army worm, harbored in such crops as vetch, bur clover, and field peas, has done considerable damage to fruit. During the season of 1907, orchards in which fenugreek was being grown were noted as being free from the army worm, while other orchards in the same section were quite badly infested.

PLANTING.

No special preparation of the land is necessary for planting fenugreek. A seed bed such as is desirable for ordinary field crops is all that is required. The best time for seeding varies somewhat in the different parts of the State. For a winter green-manure crop in southern California, in sections away from the coast, such as Pomona and Redlands, plantings should be made as early in September as possible. In sections near the coast plantings may be made later with good results, but September planting is to be advised. In northern California plantings for green manure should be made the first of October.

Fenugreek does best on a good, deep loamy soil, but such a soil is not necessary for success, as the plant does quite well on a gravelly or a sandy soil. It is not adapted, however, to a soil that will become hard, like heavy clay or adobe. The crop should be sown either broadcast or in close drills. Thirty pounds of seed per acre is necessary for a green-manure crop, while less is best for a seed crop. Care should be taken not to plant the seed too deep.

SEED PRODUCTION.

The fenugreek seed handled by American seedsmen is almost entirely imported. The demand for it has been so slight that only small stocks are handled. The imported seed comes from the Mediterranean countries, chiefly from Egypt and Palestine. The seed of fenugreek used in the orchard green-manure work in California is grown almost entirely in Orange and Ventura counties, in which localities a good crop of fine seed can be produced.

Possibly the only sections where fenugreek can be grown profitably as a seed crop are where the winters are very mild, having at most light frosts, so that with late fall seeding there will be a sufficient growth made during the winter months. An ordinary grain drill is the best implement to use in seeding. From 15 to 20 pounds of seed per acre are sufficient. After seeding, nothing is done with the crop until it is harvested. In the interior valleys an irrigation at the time of seeding is necessary.

The crop can be cut with an ordinary mower, and after a short time should be raked into windrows. Here it should be allowed to cure for several days before thrashing, which can be done with an ordinary thrashing machine. In so far as possible the crop should be taken from the windrows in the early morning, there being less shattering of the seed when handled at this time. The pods when very dry drop from the stem and dehisce, or break open slightly, although the loss of seed from this cause is not great.

The quantity of seed produced per acre varies as with any other crop, and while there are few definite figures as to yields, in Ventura and Orange counties, where the best fenugreek seed crops are produced, probably 1,500 pounds per acre is an average yield. At Chico, in northern California, plantings in $\frac{1}{20}$-acre plats yielded at the rate of 490 pounds of seed per acre, while one smaller plat yielded at the rate of 1,315 pounds per acre. The Chico plantings were made with irrigation the first half of October, 1908. The crop was harvested the 1st of June, 1909.

HAIRY VETCH.

The hairy or winter vetch (*Vicia villosa*) is not so well adapted for green-manure purposes as is the common vetch, and it has not been used except in a very limited way. Under California conditions it

makes less growth during the winter season than the common vetch, and this has prevented its larger use for green manuring. Extensive experimental tests in comparison with common vetch, as well as practical tests made by orchardists, show the same results.

While hairy vetch does not make a good winter growth, when the warmer weather of the latter part of winter and early spring comes, it makes a very vigorous start and, if left to develop fully, a heavier growth than common vetch. It also stands more dry weather without injury, and where a late spring crop is wanted it is very desirable. The handling of the crop is the same as with common vetch. From 45 to 50 pounds of seed per acre should be used in seeding.

INDIAN MELILOT.

Indian melilot (*Melilotus indica*) is quite common in waste places throughout the orchard sections of southern California and for a number of years has received some attention as a green-manure crop. However, it has never been used except in a very limited or experimental way, and this experience indicates that it has but very little value in orchard work in California.

The winter growth of melilot is about like that of bur clover, and, like that crop, its best growth is not made until too late in the winter to be turned under in February. The only place in California where melilot seems likely to prove at all valuable is on the very sandy soils, to which it is quite well adapted and on which it is often hard to get a stand of other green-manure crops.

SUMMER GREEN-MANURE CROPS.

The question is sometimes asked whether it is advisable to grow a summer green-manure crop as well as a winter crop, thus enabling one to add two crops a year to the soil instead of one. Where water for irrigation is available there is no difficulty in doing this. However, the practice is not to be advised except under very exceptional conditions. The enormous quantity of water used by a green-manure crop in its growth makes it decidedly objectionable for summer use in an orchard, where all the water available is usually needed for the orchard crop.

The growing of a summer green-manure crop also necessitates the discontinuance of cultivation of the soil, which except on the most open soils would be more or less detrimental if continued for a long period. There may be instances, however, where it is desirable to build a soil up as rapidly as possible. In such cases a summer green-manure crop may be used to advantage. For this purpose the Whippoorwill variety of cowpea has been found the best of any crop tested.

RESULTS OF GREEN MANURING IN CALIFORNIA.

There have been no definite tests made in California to determine the results in an increased yield of fruit or improved quality of the same from the use of green manures. The only evidence available is that of general observation and the experience of the orchardists.

While orchardists differ to some extent in conclusions, they generally are favorable to the practice, as its continued and growing use attests. Careful observations also show the beneficial results of green-manure crops in a more thrifty appearance of the trees, an improved condition of the soil, and a better quality of the fruit. The belief is quite general that the yield, also, is increased. Orchards in which a few years ago there were unthrifty trees with yellowish-colored leaves now, after several years' use of green-manure crops, show a decided improvement in color and general appearance. The work of the California experiment station has demonstrated that gummosis of citrus trees is brought on by unfavorable soil conditions and that in remedying such conditions green manures serve a very useful purpose.[a] Orchards in which green manures have been used for a long time are but little affected by this disease.

The improved condition of the soil when green manures have been used for some time has been readily noticeable to those handling an orchard. The heavier soils have become quite open and friable and the sandier soils more loamy. Beneficial results in the conserving of rainfall and the prevention of washing of the soil have also been very apparent. Most soils that wash badly do so because they are deficient in organic matter. Green manuring, by the improvement of the mechanical condition of the soil, not only prevents washing, but the presence of the growing crop on the land prevents gullying during the rainy season. This is of particular importance on sloping lands.

RESULTS OF TESTS WITH VARIOUS LEGUMES.

From the fact that the addition of humus to the soil is one of the main objects in using a green manure, it necessarily follows that, other things being equal, the crop producing the heaviest vegetative growth is the most desirable. To determine the comparative amount of vegetative growth made by various crops the green weight per acre has been determined, as shown in Tables I, II, and III. However, these figures can be taken only as indicating in a general way the amount of organic matter returned to the soil, as no corrections were made for the varying moisture content of the different crops.

[a] Bulletin 200, California Agricultural Experiment Station. 1908.

In Table II the weight of the green material produced per acre is presented, together with the weight of the same when dry. The green material was weighed at the time of cutting, and for estimates of the yield of dry matter was weighed again in thirty days. During this period the various crops had become nearly dry, but undoubtedly the moisture content, even at this time, would vary to some extent, although not nearly so much as in the green state.

That the yield of green material as shown by its weight may be misleading without proper correction for the moisture it contains is shown in Table II in the case of the two lots of black-purple vetch. The first lot was quite succulent at the time of cutting, and consequently was very heavy in the green state, while the other was a little older and less succulent, and so was much lighter. The latter did not show the heavy loss in drying that the former did, however, and thus the difference in the amount of organic matter of the two is not nearly so great as the difference in the weights of the green matter would indicate. In this connection it should also be noted that varying yields are often due to a difference in the stands rather than to differences in the growth of the crop. In the comparative data presented in the tables this has been reduced to a minimum by selecting for this purpose crops with as nearly uniform stands as possible.

From all data available it seems clear that of the commonly grown green-manure crops, vetch, peas, bur clover, and fenugreek, the vetch returns the most organic matter to the soil and the peas the least. The light yield of peas is not due to a lack of stem growth, which on the contrary is always good, but to the generally poorer stand and more open habit of growth. Bur clover, while weighing heavy green, is very succulent when young, and when compared with an equal weight of green vetch represents much less organic matter. Fenugreek yields well, but not so much as vetch.

In securing the yield of green manure per acre, as presented in Table I, the plants growing on a plat 6 by 20 feet were cut and weighed green and the yield per acre computed from these weights. In Table II a plat 10 by 10 feet square of each crop was cut and weighed green and the yield per acre thus calculated. The same was weighed again in thirty days, as shown in the table, giving the yields of the dry matter. In Table III the weights shown were taken from crops being grown by orchardists during the winter of 1908–9 at the places mentioned in the table and are representative of these crops as grown under actual orchard conditions. To obtain the results the plants growing on a space between four trees were cut and the yield per acre calculated from such weights.

TABLE I.—*Growth of plants and weight per acre of green-manure crops sown with irrigation October 19, 1907, at Chico, Cal.*

Name.	Rate of seeding.	Height of plants, March 18, 1908.	Weight of green manure, March 28, 1908.
	Pounds.	*Inches.*	*Pounds.*
Black bitter vetch	130	26	32,056
	34	26	23,236
Black-purple vetch	56	30	24,042
	34	30	15,609
Woolly-podded vetch	17	28	18,876
Hairy vetch	56	15	11,616
Common vetch	39	12	7,623
Lathyrus sativus	56	16	19,239
Tangier pea	56	18	13,794
Field pea	159	26	15,944
Horse bean	164	28	10,890

TABLE II.—*Growth of plants and weight per acre of green-manure crops sown with irrigation October 5, 1908, at Chico, Cal.*

Name.	Rate of seeding.	Height of plants, March 15, 1909.	Weight of dry matter, March 16, 1909.	Weight of dry matter, April 16, 1909.	Proportion of dry to green matter.
	Pounds.	*Inches.*	*Pounds.*	*Pounds.*	*Per cent.*
Black-purple vetch	62	32–36	40,565	3,675	9.0
	45	36–40	14,374	2,321	16.8
Woolly-podded vetch	48	30–36	25,047	2,933	11.7
Black bitter vetch	76	20–22	27,660	3,776	13.6
	49	20–22	14,374	2,130	14.8
Horse bean	149	30–36	21,130	2,634	12.4
Fenugreek	29	16	13,721	1,783	12.9
Tangier pea	72	17	12,840	1,646	12.8
Bur clover	21	14–16	11,980	735	6.1
Hairy vetch	31	8–15	5,880	871	14.8
Common vetch	33	10–18	2,831	.....	.....

TABLE III.—*Weight of green-manure crops growing in orange orchards in California.*

Name.	Place.	Weight of green matter per acre.	Weight of green matter per 0.718 acre.[a]
		Pounds.	*Pounds.*
Tangier pea	Redlands	29,093	20,888
Common vetch	do	13,578	9,749
Malva rotundifolia	do	19,800	14,216
Bur clover	do	16,347	11,737
Field pea	do	7,260	5,212
Fenugreek	Santa Paula	11,745	8,432
Common vetch	do	19,140	13,742

[a] This equals the part of an acre usually covered by a green-manure crop in an orchard.

PROMISING GREEN-MANURE CROPS.

As shown by Tables I and II, giving comparative yields, there are several plants very promising for green-manure purposes as compared with common vetch and field peas. The claim of superiority for these plants is largely due to their ability to make more growth

during the cool weather of the winter, thus affording a heavier growth to be turned under. This is an especially strong point where it is desirable to turn the crop under as early as possible, as is the case in the citrus orchards of southern California. The plants referred to are the black-purple vetch, the black bitter vetch, the woolly-podded vetch, the horse bean, and the Tangier pea.

BLACK-PURPLE VETCH.

The black-purple vetch (*Vicia atropurpurea*) is one of the most promising green-manure crops tested for California. Its general

FIG. 7.—A field of black-purple vetch at Chico, Cal.

appearance and habit of growth are about like those of the common vetch (fig. 7), although it is very distinct from that species. The superior value of black-purple vetch when compared with common vetch lies in its ability to make a much stronger growth during the cool weather of early winter. This, as noted elsewhere, is an especially desirable quality in a green manure to be turned under in February.

The root system of black-purple vetch, which is similar to that of common vetch, is well covered with medium large nodules. The stems, aside from making a strong growth, are of such a texture as

to enable them to stand much trampling or other hard usage without injury.

The time and manner of seeding this crop are much the same as with common vetch. As the seed is a little smaller, however, a smaller quantity may be used in seeding. From 50 to 60 pounds per acre is advised.

BLACK BITTER VETCH.

Black bitter vetch (*Vicia ervilia*), another very promising green-manure crop for California, is different from most other vetches in that it is upright in its habit of growth, rather than vinelike. Like

FIG. 8.—A field of black bitter vetch at Chico, Cal.

the black-purple vetch, it possesses the desirable quality of making a good growth during the cool weather of early winter and is much superior to common vetch in this respect. (See fig. 8.) In this connection it should be noted that different strains of this vetch have given different yields, so that some will doubtless be found superior to others.

Its upright habit of growth makes this crop very easy to turn under with an ordinary moldboard plow. The viny growth of common vetch makes it objectionable to some orchardists. The root system, while quite well covered with nodules, is perhaps not so extensive as that of some of the other vetches. The plant has a more definite

central root, or taproot, than common vetch, and the fibrous roots tend to penetrate more deeply. The seeding habits are much better than those of other vetches. The pods shatter but very little, which much facilitates the harvesting of the seed.

Black bitter vetch is grown very extensively in the Mediterranean region, where the seed is a commercial product. The fact that the seed of this plant can be imported at a reasonable cost makes it possible to supply the trade at once. On account of the plant branching but little it is necessary to use a slightly larger quantity of seed in seeding than with common vetch. Seventy pounds per acre is recommended. Aside from the quantity of seed per acre used, the crop should be handled like common vetch.

WOOLLY-PODDED VETCH.

Woolly-podded vetch (*Vicia dasycarpa*) resembles hairy vetch quite closely, both in appearance and in agricultural value.

In comparative tests the woolly-podded vetch has made a stronger growth during the cool weather of early winter than the common or the hairy vetch, but not so strong as the black-purple vetch or the black bitter vetch. As soon as the warmer weather of the latter part of winter comes it is one of the most vigorous growers and its ultimate yield is very heavy. Thus, while it will serve very well as a crop to be turned under in early winter its special value is for conditions where the crop can be allowed to remain a little later in the spring. For sowing without irrigation in deciduous orchards it may be of special value.

Woolly-podded vetch stands trampling well and for orchard use is in this respect equal, if not superior, to common vetch. The root system is about like that of common vetch and is well covered with medium large nodules.

In growing woolly-podded vetch it should be handled as common vetch, except that a little less seed may be used in seeding. Fifty pounds per acre is sufficient.

HORSE BEAN.

The horse bean (*Vicia faba*) has been but little grown in California. The broad bean, however, which differs from the horse bean only in having larger and broader seeds and pods, has been grown as a vegetable for a number of years in a few localities.

Experimental tests in California during the past few years indicate that the horse bean has considerable value as a green-manure crop, especially in the southern part of the State. (See fig. 9.)

The plant has an upright stem which is quite leafy, but little branched. The leaves, as well as the stems, are quite large, but com-

paratively soft and succulent until well matured. The root system consists of a strong taproot, with a fairly well-developed fibrous system radiating from this. The roots penetrate quite deeply into ordinary soils and aid in overcoming "plow sole." The taproot, as well as the smaller roots, when well inoculated has many large nodules, indicating that it is a good nitrogen gatherer. In southern California horse beans are usually well inoculated and have many large nodules. In northern California, thus far, they have had very few or no nodules the first year they have been grown. Consequently, when grown without artificial inoculation they amount to but little, although when inoculated they succeed quite well.

FIG. 9.—View in a citrus orchard in southern California, showing horse beans grown as a green-manure crop.

Although the stems of the horse bean are quite large they decompose readily when turned under for green manure. In comparison with other green-manure crops horse beans make a good growth, but in an orchard will not withstand trampling like the vetches. As the seeds are large a considerable quantity is required in seeding, unless the field is planted in drills more than the ordinary distance apart. As the individual plants make a comparatively large growth they will stand this method of planting, and if sown in drills 18 or 24 inches apart a good yield will be secured. The season for planting is the same as that of vetch.

TANGIER PEA.

The Tangier pea (*Lathyrus tingitanus*) was originally introduced into this country from northern Africa. It is an annual legume resembling in general the garden sweet pea, to which it is related.

During the past few years considerable attention has been given to the Tangier pea to determine its value as a green-manure crop, and results thus far indicate that it is of considerable value for this purpose. It makes a strong growth, yielding a heavier tonnage per acre than the common vetch (see Tables I, II, and III). Its dense growth enables it to overrun and smother out weeds, which is one of the very noticeable qualities of this crop. Though the stems are quite large they are not very succulent and stand considerable rough usage, being well adapted for orchard use in this respect. The large growth made by Tangier peas makes them somewhat difficult to turn under with an ordinary moldboard plow; with a disk plow but little trouble in this respect will be experienced.

The root system is well developed. It has a more nearly definite central root than vetch, and the roots penetrate the soil more deeply. The nodules are large and numerous, indicating that the plant is a good nitrogen gatherer.

For a green-manure crop Tangier peas should be handled like common vetch, except that the seeding should be heavier, from 70 to 75 pounds of seed per acre being required for obtaining the best results.

COST OF SEED OF GREEN-MANURE CROPS.

The cost of seed of green-manure crops is a factor of considerable importance in determining their relative value. The high price of seed may be the cause of the elimination from use of an otherwise good crop. In most orchard sections it is hardly practicable for the orchardist to attempt to raise his own seed, though with crops having good seeding habits this could be readily done. The commercial seed grower will very likely be depended upon for the supply of seed needed. The price that growers will pay for any new crop will probably be largely determined by the price of seed of common vetch and of field peas. A slightly higher price for a superior crop would undoubtedly be paid. However, a superior crop and cheap seed are what is desired.

The practice of allowing enough seed to ripen in the orchard to volunteer a crop from year to year is the cheapest method of seeding a green-manure crop, but this is practicable only in deciduous orchards without irrigation, where the returns will justify but very little expense in connection with such a crop. Under such conditions bur clover in particular can be effectively used.

TABLE IV.—*Seed production per acre of various legumes at Chico, Cal., 1909. Plats one-twentieth acre.*

Name.	Rate of seeding.	Yield of seed.
	Pounds.	*Pounds.*
Tangier pea	72	210
Tangier pea	77	630
Fenugreek	28	490
Fenugreek	21	490
Black bitter vetch	48	600
Black bitter vetch	45	1,800
Black bitter vetch	76	1,980
Black-purple vetch	58	300
Black-purple vetch	36	380
Black-purple vetch	36	580
Black-purple vetch	48	400
Woolly-podded vetch	45	290

In Table IV is presented the seed yield of various new green-manure crops discussed in this bulletin. These yields were taken from $\frac{1}{20}$-acre plats that had been sown primarily for a green-manure crop test and not for seed production. So the yields in some instances are much lighter than would have been the case had the crop been sown for seed.

It is quite probable that at Chico, where these crops were grown, conditions are not so favorable for the seed production of such plants as the woolly-podded vetch and the black-purple vetch as are the conditions in western Oregon, where seed of common vetch and hairy vetch is grown commercially. This is probably also true of the Tangier pea, though not so much so of the black bitter vetch, which does well at Chico. The yields presented in the table and the general character of the crops indicate that seed should be produced as cheaply as that of common and of hairy vetch, and in the case of black bitter vetch somewhat more cheaply. The seeding habits of black bitter vetch are such that an orchardist could easily raise his own seed if necessary, and where it is desirable to grow some crop in a young orchard he might raise the seed with profit.

Of the crops mentioned, the production of seed will cost most with the Tangier pea and the woolly-podded vetch, and least with the black bitter vetch. The cost of seed of common vetch and field peas varies from year to year. Seed of common vetch during the past few years has varied from $3\frac{1}{2}$ to 5 cents per pound. When seeding at the rate of 60 pounds to the acre this would make the cost of seed from $2.10 to $3 per acre.

Seed of field peas has been about the same price per pound as that of common vetch, but as 80 pounds of seed per acre are needed in seeding, this makes the cost from $2.80 to $4 per acre.

Bur clover seed is advertised at from 25 to 30 cents per pound, hulled. When seeding at the rate of 20 pounds of seed per acre this makes the cost of seed from $5 to $6 per acre.

The wholesale price of fenugreek seed in the European market is from 2½ to 3 cents per pound. The price to the grower would of course be somewhat in advance of this, but should not exceed 5 or 6 cents. When 30 pounds of seed per acre are used, this would make the cost of seeding from $1.50 to $1.80 per acre.

Black bitter vetch seed, though not handled in quantity by American seedsmen, can be secured in foreign markets and imported at a cost that should make the price to the grower about the same or less than that of common vetch. When seeding at the rate of 70 pounds of seed per acre, this would make the cost of seeding from $2.40 to $3.50 per acre. As stated elsewhere, the fact that black bitter vetch yields a heavy crop of seed in California and has exceptionally good seeding habits should make it possible to place California-grown seed on the market at a much less cost than that of common vetch.

SUMMARY.

California soils, though often very fertile, are generally deficient in humus.

Within recent years green-manure crops in California have been given special attention.

The only places where green manures are being used extensively are the citrus and walnut orchards of the southern part of the State.

Deciduous orchard sections of the State are using practically no green-manure crop.

By the use of green manures a generally improved condition of orchards has been secured, as shown by a more healthy appearance of the trees and more and better fruit.

The early seeding of green-manure crops is desirable for obtaining the best results.

Green manures should be turned under before the trees start new growth in the spring.

Heavier seeding than is ordinarily practiced is advised.

Common vetch and field peas are the most generally used green-manure crops, the vetch being the most popular.

Peas or common vetch sown in the fall without irrigation will not, except in the most favorable years, make sufficient growth to be turned under early as a green manure, but when thus sown will make a good growth later in the spring.

Field peas, common vetch, and bur clover are adapted to quite varied conditions, and are being grown in a limited way throughout the State.

In any part of the State having a mild winter a green-manure crop of peas or common vetch will succeed if sown early in the fall with irrigation.

Bur clover seems to be of most value for deciduous orchard conditions, while the woolly-podded vetch promises to be of value for the same conditions.

Fenugreek and bur clover are used to a limited extent, fenugreek being especially adapted to the region near the coast.

Hairy vetch is not well adapted for use as a green-manure crop in California.

Black bitter vetch, black-purple vetch, woolly-podded vetch, horse beans, and the Tangier pea are promising new green-manure crops in comparison with common vetch.

Green-manure crops need no inoculation in California, horse beans in the northern portion being the only known exception.

The growing of a summer green-manure crop in California orchards is not advisable.

Local as well as sectional conditions in the various parts of the State vary considerably, and must be taken into consideration in determining the best crop for green manure as well as the best method of handling the same.

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